

SHAPING THE LAW OF WEATHER CONTROL

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Man seems always to have assumed that storms, the fall of rain and snow, and other weather changes were subject to some sort of control.¹ From anthropomorphic myth as an explanation, belief and law turned to witchcraft,² but by the eighteenth century, weather phenomena were ascribed to a Providence whose decisions were legally inscrutable.³ Precipitation fell from the riven sky in expression of the "act of God" and human responsibility extended only to reasonable foresight and precaution, unless a contract of insurance was involved. From Lord Mansfield⁴ to present-day judges, events of this kind have been held "not of human origin and not controllable by human power."⁵ Each of these varying conceptions reflected accretions to knowledge and

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1. Some details of early myths and practices may be found in Frazer, *The Golden Bough*, C. V. (abr. ed. 1937). Pareto has analyzed the primitive hypostatization of storms in 1 TRATTATO DI SOCIOLOGIA §§ 186-198 (1916), (ed. and tr. Livingston et al. as *THE MIND AND SOCIETY*, 1935) tr. 117-127.

2. See, for example, TAYLOR, *THE WITCHCRAFT DELUSION IN COLONIAL CONNECTICUT, 1647-1697* (1908); GEMMILL, *THE SALEM WITCH TRIALS* (1924). There is a selection of references to the literature on witchcraft in the English law in ALLER, *LAW IN THE MAKING* 64n. (1st ed. 1927); and see McKenna, *Witchcraft, An Obsolete Crime*, 13 MARQ. L. REV. 18 (1928).

3. See 9 Geo. 2, c. 5, §§ 3, 4 (1736).

4. *Trent and Mersey Navigation v. Wood*, 4 Dougl. 287, 26 E.C.L. 479, 99 Eng. Rep. 884 (1785); *Forward v. Pittard*, 1 T.R. 27, 1 Eng. Rul. Cas. 216, 99 Eng. Rep. 953 (1785).

5. 1 SHERMAN AND REDFIELD, *NEGLIGENCE* § 32 (Zipp ed. 1941). GA. CODE §§ 102-103 (Park 1937) provides, for example: "Act of God means an accident produced by physical causes which are irresistible or inevitable, such as lightning, storms, perils of the sea, earthquakes, inundations, sudden death or illness. This expression excludes all idea of human agency." CALIF. CIV. CODE § 3526 (Deering 1941) has: "No man is responsible for that which no man can control." Cases applying the principle are *Florida Power Corp. v. Tallahassee*, 154 Fla. 638, 18 So.2d 671 (1944) (hurricane); *Chandler v. Aetna Ins. Co.*, 188 So. 506 (La. 1939) (tornado); *Central Georgia Electric Membership Corp. v. Heath*, 60 Ga.App. 649, 4 S.E.2d 700 (1939) (lightning). General discussions can be found in Angoff and Chappers, "*Hurricane of 1935*"; *When not an Act of God?* 9 LAW SOC.J. 527 (1941); Paton, *Act of God in the Law of Tort*, 15 CAN.B.REV. 724 (1937); Sidmon, *Act of God*, 8 ST. LOUIS L.REV. 124 (1923).

alterations in theories.⁶ Nevertheless, the facts of rainmaking had apparently been the same through the centuries—man had never had actual technical control over even the local weather referred to in the judges' decisions. Even recently, experts despaired of intervening in weather changes directly at any distance above the ground, counselling that ". . . we must take our rainfall as it comes. . . ." ⁷ Weather seemed destined to continue its position as "the most violent variable in man's plans and enterprises." ⁸

In the past two years, however, a revolution in rainmaking has taken place. Rapid scientific advances in colloid chemistry, meteorology, electronics and other fields have given rise to the assertion that developments in modification of weather phenomena are "possibly as important, in terms of benefits to mankind, as atomic energy." ⁹ Icing conditions and hailstorms may be eliminated, clouds and fogs dispersed, rain and snow produced, and hurricanes and other rain and snow storms ameliorated or diverted to areas where they will cause little harm.

Although the factual future of these discoveries is still in doubt, there is virtual certainty that "sooner or later some cloud sower is going to reap a legal whirlwind." ¹⁰ An attempt will be made below to present a preliminary analysis of the legal problems involved in artificial modification or control of the weather, with some suggestions as to the direction which satisfactory solution must take. Although specification of legal minutiae would defy the inadequacies and obsolescence-rate of present data, the physical nature of the phenomena dictates broad

6. White has traced the trend of thought to another purpose in his *Man's Control Over Civilization: An Anthropocentric Illusion*, 66 SCI.MON. 235 (1948); cf. Bowerman, *Life Among the Sunspots*, 56 POP.ASTRON. 13, 23 (1948).

7. Holzman, *The Hydrologic Cycle*, in CLIMATE AND MAN, YEARBOOK OF AGRICULTURE, 1941 (hereafter CLIMATE AND MAN) (U.S. Dept. Agriculture) 238.

8. *Weather is the Most Violent Variable in Man's Plans and Enterprises*, Life, September 13, 1943, p. 89; U.S. News, June 27, 1947, p. 24. Hopes were raised and questioned from time to time; see Reichelderfer, *Is it Possible for Man to Change his Climate?* 55 NAT.HIST. 1 (1946); *Weather Control?* Time, July 5, 1943, p. 90.

9. Suits (Director General of General Electric Research Laboratories), quoted in Spencer, *The Man Who Can Make It Rain*, Saturday Evening Post, October 25, 1947, p. 24. The comparative degree is also employed: "Weather control may have greater implications than atomic energy," 25 CHEM. AND ENG. NEWS 3050 (1947). For dissent, see Drake, *Rainmakers are All Wet*, '48 (magazine), March 1948, p. 61.

10. Spencer, *supra*; Life, September 8, 1947, p. 53. Time, December 22, 1947, p. 44, triples the interrogative: "Then what will the thirsty neighbors do? Have they a right to sue the dry-ice man? Or must they all get airplanes and try to bring down their own clouds?" See also, Whitney, *Storm Over Rain*, New York Times Magazine, December 14, 1947, p. 33. When such accounts go further, the temptation to sacrifice thought to humor often leads to vague calls for a "Coordinator of Snowflakes," or a "Secretary of Rain and Snow." This seems a logical point for the writer, also, to drop the eye-catching but discredited misnomer, "rainmaking," in favor of "weather modification" and "weather control."

lines of inquiry and resolution. If major mistakes in this regard can be avoided, the lawyer's law will not be so awkward and helpless, vis-a-vis technology, as popular statements seem to imply.

SCIENTIFIC ADVANCES IN WEATHER MODIFICATION AND THEIR POSSIBLE APPLICATION

The mighty phenomena of weather, covering the globe, represent a precarious balance of enormous forces and masses which may be "triggered" into changing their courses and effects by the application of a relative finger-touch. Colloido-meteorological research would supply the necessary trigger in the form of a nucleation technique¹¹ which stimulates conversion of the atmosphere's potential energy, stored in unstable air, into the kinetic energy of weather.¹² Without this artificial nucleation, thermodynamically unstable conditions may be checkmated by colloidal stability, and, therefore, pass on or dissipate without having produced the weather benefits of which they are capable; or they may become intensified until the ultimate spontaneous outbreak is vastly harmful.¹³

A necessary prerequisite to the channeling of weather phenomena into desired paths by means of nucleation is a proper understanding of the changes involved in the condensation and sublimation¹⁴ of water vapor and its precipitation.¹⁵ It had long been known that even

11. The term *nucleus* is used herein not in the special sense of the central portion of an atom, but in the more general meaning of a central mass, or kern, about which matter is gathered. *Nucleation* refers to the generation or introduction of such nuclei and the immediate effects thereof. For other suggested, though lesser-known techniques, see note 54 *infra*.

12. See Bergeron, *On the Physics of Cloud and Precipitation*, MEMOIRE L'UNION GÉODÉSIQUE ET GÉOPHYSIQUE INT. (1933); Findeisen, *Die Kolloidmeteorologischen Vorgänge bei der Niederschlagsbildung*, 55 *Meteorologische Zeitschrift* 121 (1933). In his concluding section Findeisen said (at 133) [translation is the present writer's]: "... every substantial rain is triggered [auslösen] by sublimation and ... the sublimation nuclei play a decisive role. ... Something that seems very insignificant from a quantitative point of view, and that has not until now been considered in weather analysis, is decisive for the whole development of the weather. ... One dares say that it will in time be possible by relatively small efforts to create rain artificially, and to remove the danger of icing and hail. By the energy transformations caused by such a procedure, other aspects of the weather also, e.g. temperature and wind, will, within limits, be influenced, which probably could never be changed directly to any considerable extent by direct technical means."

13. See GENERAL ELECTRIC RESEARCH LABORATORY (LANGMUIR et al.), *METEOROLOGICAL RESEARCH* [hereafter FIRST CIRRUS REPORT] 5-7, 9 (1947); Rex, *The Meteorological Research Program of the Office of Research and Inventions, Navy Department*, 27 *BULL. AMER. METEOR. SOC.* 373, 374 (1946).

14. Here *sublimation* is the passage of water from vapor to ice without apparently liquefying.

15. See the quotation from Findeisen, note 12 *supra*, and the short statements in TREWARTHA, *AN INTRODUCTION TO WEATHER AND CLIMATE* 144-145, 175-179, 235-291

though water's freezing point is ordinarily 0 degrees Centigrade, moisture sufficient for precipitation exists in clouds below that temperature (*i.e.*, supercooled clouds) without turning into ice. This is due to the fact that spontaneous crystallization occurs only at about minus 35 degrees; only if sublimation nuclei are present can ice crystals grow at higher temperatures. Until very recently, no economically feasible means of causing crystallization on a large scale was known. By 1946, however, the researches of Langmuir and Schaeffer—first on smoke generators and later on aircraft icing¹⁶—had borne fruit. They discovered that solid carbon dioxide (dry ice) will spontaneously generate ice nuclei in supercooled clouds, through localized chilling of the air surrounding the dry ice. With Vonnegut's aid, they also learned that chemicals whose crystal structures and molecular dimensions sufficiently resemble that of ice will act as sublimation nuclei; the chemical now in use is silver iodide. A very small quantity of either "dry ice" or silver iodide, properly dispensed, will turn the supercooled cloud into unusually minute ice crystals, thus preventing or at least delaying ordinary precipitation. A still smaller quantity begins a normal precipitation process and the moisture falls from the cloud as snow. If relative humidity below the cloud is not too low, the snow will reach the ground. If temperatures above freezing are encountered, the form of the precipitation will be rain.¹⁷

At first, it was thought that only clouds which possessed supercooled

(2d ed. 1943); BYERS, *GENERAL METEOROLOGY* cc. 14, 20, 22, 23 (1944). Discussion of meteorological background and of the physics of precipitation, clouds, fog and aircraft icing is contained in Lowell, *Condensation and Precipitation*, in *HANDBOOK OF METEOROLOGY* 252 (Berry ed. 1945); HEWSON AND LONGLEY, *METEOROLOGY, THEORETICAL AND APPLIED* cc. 18-20 (1944); HUMPHREYS, *PHYSICS OF THE AIR* (1940).

16. Basic Icing Research by General Electric Company, Fiscal Year 1946, USAAF Tech.Rept.No.5339 (1947).

17. For accounts of theory and experiments, see: FIRST CIRRUS REPORT; Schaefer, *Production of Ice Crystals in a Cloud of Supercooled Water Droplets*, 104 *SCIENCE* 457 (1946); Vonnegut, *Nucleation of Ice Formation by Silver Iodide*, 18 *JOURN. OF APPLIED PHYSICS* 593 (1947); Schaefer, *Man-made Snow*, 69 *MECH.ENG.* 32 (1947); Langmuir, Schaefer and Vonnegut, addresses to the American Physical Society, reported in *New York Times*, January 31, 1947, p. 16, col. 1; Kraus and Squires, *Experiments on the Stimulation of Clouds to Produce Rain*, 159 *NATURE* 489 (1947); Reichelderfer and another, *Meteorology*, in *ENCYC. BRIT.BOOK OF THE YEAR: 1947*, 491, 492; Hawley, *SMALL WONDER: THE STORY OF COLLOIDS* (1947) 83-84; Kaempffert, *Making Weather to Order*, *New York Times Magazine*, July 20, 1947, p. 9, repr. in *SCIENCE YEARBOOK OF 1948* 213 (Ratcliff ed.). For surveys and accounts in the centuries-long history of efforts to produce artificial precipitation, see Humphreys, *RAINMAKING AND OTHER WEATHER VAGARIES* (1926); McAdie, *A CLOUD ATLAS* (1923); Jeffreys, *Artificial Production of Rain*, 108 *NATURE* 313 (1921); Harrington, *Weather Making, Ancient and Modern*, *NAT.GEOGR. MAG.*, April, 1894, p. 35; Report of the Agent of the Department of Agriculture for Making Experiments in the Production of Rainfall, *Sen.Exec.No. 45*, 52nd Cong., 1st Sess. (1892); Espy, *LETTER TO THE FRIENDS OF SCIENCE* (privately pub. 1845, Yale University Library).

portions could be induced to precipitate artificially; but Langmuir has recently suggested that rain will be induced by the introduction of ordinary water droplets or ice particles into cumulus clouds which have no supercooled parts, but instead, possess high moisture content and considerable vertical size and updraft. The process may be roughly described as a "chain reaction," in which droplets grow to critical size and, before falling out of the cloud, shed smaller droplets which repeat the process.¹⁸

Use of aircraft, rockets and other carriers for dry ice, and of ground generators for silver iodide will permit large sections of the atmosphere to be seeded and modified by means of the techniques outlined above.

The ultimate extent to which weather control can be utilized is rendered speculative by the presently small number of expertly conducted field experiments in most forms of applied weather modification, and by the difficulties of proper instrumentation of even small scale operations. As a result, forethought on legalities must proceed upon the predictions of those conversant with the factual field. There is conflict in these predictions; but to obtain a wide scope, we must here focus upon the affirmative views.¹⁹ Upon this basis, some detailing of possible applications of the discoveries already outlined is necessary if the social and economic factors which press toward early development and utilization of them, or of other methods, are to be grasped. Some idea of the economic interests involved may be gathered from the estimate of savings made possible by present United States Weather Bureau services, which make no effort to change weather but merely give information about it. Its reports have resulted in annual avoidance of two billion dollars worth of property damage by agriculture, industry, business, commerce and utilities; and the value of increased production made possible by weather forecasts is another two billions

18. *Langmuir Announces New Rain Propagation Theory*, New York Times, November 18, 1947, p. 31 col. 2, abs. in 25 CHEM. AND ENG. NEWS 3568 (1947). See also Brun and Demon, *Sur la Formation Artificielle de la Pluie*, 225 ACADEMIE DES SCIENCES-COMPTES RENDUS 505 (1947).

19. For a negative view, after a series of experiments by the Cloud Physics Project of the armed services and the Weather Bureau directed toward the "rainmaking" aspect of weather control, see *Time*, December 6, 1948, p. 50. The official report is quoted as saying: "The responsible scientists of the project interpret the long series of experiments to mean that recently proposed artificial weather modification processes are of relatively little economic importance." How many of the applications other than production of rain were attempted is not indicated in *Time's* report. Continued Government interest in the field seems indicated by Secretary of Defense Forrestal's current request to Congress to enact a statute to "protect contractors engaged in cloud modification experiments against claims for damages by third parties." N.Y. Times, Jan. 13, 1949, p. 25, col. 7. Other researchers have deferred attempts with other techniques until the forecasting problems already mentioned are solved. Zworykin, *Discussion of the Possibility of Weather Control*, reported in *Aeron. Eng. Rev.*, Feb. 1947, p. 26.

annually. This does not include savings to air commerce, which are "incalculable but large."²⁰

The specific applications described below were selected on an eclectic basis, without any attempt made to order them according to importance or to be exhaustive. Most of them have been pointed out in general by the researchers, and the intention here is to collate expressions of view and locate them in a statistical context.

Storm modification

THUNDERSTORMS. Recent research makes it seem probable that if dry ice is dropped over incipient thunderstorms as soon as the cloud tops reach freezing level, the development of the storm may be profoundly modified. Storms would be longer but less severe, and hail would be avoided.²¹ The value of such results, although difficult to estimate precisely, may be gauged by the fact that three-fourths of the United States have thunderstorms on an average of 30 or more days annually, the southeast quarter ranging from 50 to 90 days.²² Non-tornadic storms caused an average of 217 deaths and almost \$33,000,000 of property damage annually from 1916 to 1941,²³ and much of this loss was due to thunderstorm squalls.²⁴ Tornadoes, which develop under "thunder" conditions, caused an average of 239 deaths and \$11,000,000 of damage in each year of the same period.²⁵ Aside from the harm done by hail and lightning, the hazard to air commerce created by thunderstorms is common knowledge.

20. Hearings before the Subcommittee on Appropriations on Department of Commerce Appropriations Bill for 1948, 80th Cong., 1st Sess. 911 (1947). As to air commerce compare Lederer, *Loss Programs of Civil Aviation*, reported in *Aeron.Eng.Rev.*, March, 1948, p. 27: "The outstanding factor in producing fatal or potentially fatal airline accidents over a period of years is the error made in approach and landing during poor weather conditions. If this factor were eliminated about 40 percent of fatal or potentially fatal airline accidents would go with it." Some technicians regard "the current solution of all weather flying and consequent improvement in the dependability of schedules as the first task confronting the airlines today. . . ." *New York Times*, March 21, 1948, p. 51, col. 3.

21. **FIRST CIRRUS REPORT 11.** This statement seems to refer to the intra-air mass thermally induced thunderstorm, which is the most common type. (Although called "local," in the United States it may "travel a few hundred miles and affect a few thousand square miles," Visher, *Thunderstorms*, 66 *Sci.Mon.* 335, 336 (1948)). But there seems no reason why it may not apply, with some qualification, to other intra-air mass and frontal thunderstorms. Attempts to break heat waves by inducing thundershowers are noted *infra*.

22. Visher, *Thunderstorms*, 66 *Sci.Mon.* 335, 337 (1948). The map at 339 gives month-frequencies.

23. **METEOROLOGICAL YEARBOOK: 1941 7** (U.S.Wea.Bur. 1943).

24. Visher, *op. cit. supra* note 22, has extended consideration. He would give \$200,000,000 yearly instead of the lower figure just mentioned.

25. **METEOROLOGICAL YEARBOOK: 1941 15** (U.S.Wea.Bur. 1943). In 1947 tornado losses were 306 lives and \$24,000,000. 75 *Mon.Wea.Rev.* 247 (1947).

a. *Hail*. This phenomenon of thunderstorms occurs almost everywhere in the United States, but most frequently on the Great Plains where an average of one thunderstorm in ten is accompanied by hail. In the country as a whole, annual hail damage was \$13,300,000 in the years 1916 to 1941.²⁶ As already indicated, nucleation techniques applied to incipient thunderstorms could eliminate hail.²⁷

b. *Lightning*. The "hammer of Thor" causes 700 to 800 deaths and twice as many personal injuries, plus fire damage of \$12,000,000 each year.²⁸ Since lightning results from the vigorous convection of thunderstorm cells, it seems likely that modification of the storms' severity could reduce lightning damage.

SNOWSTORMS. In addition to the more obvious damage caused by snowstorms, they give rise to one form of indirect economic loss—the expense of snow removal—which is of substantial importance in urban and industrial areas, especially railroad yards and airports. For example, snow removal costs New York City about \$4,000,000 a year,²⁹ and clearing the abnormal snow of December 26, 1947 alone cost over \$6,600,000, the snow and ice cover meanwhile causing 2,641 cases of personal injury and property damage.³⁰ It has been suggested that snowstorms may be "triggered off" earlier in time than they would naturally have occurred, thus causing the fall to take place away from urban and industrial areas;³¹ or that a change of direction might be induced.³²

26. HEWSON AND LONGLEY, *METEOROLOGY, THEORETICAL AND APPLIED* 376 (1944). *METEOROLOGICAL YEARBOOK: 1941* 14 (U.S.Wea.Bur. 1943). A single hailstorm may cause almost incredible damage; on July 21, 1947, one moving over a path 5 to 13 miles wide through three Nebraska counties caused estimated losses of \$3,000,000 in 90 minutes. 75 MON.WEA.REV. 135 (1947).

27. FIRST CIRRUS REPORT 11; Visher, *Thunderstorms*, 66 SCI.MON. 335, 340 (1948): "Indeed it is scientifically highly probable that dry ice dropped into a thunderhead from which damaging hail is falling will cause a reduction of the hail. This is because the dry ice produces a more simple reaction, not the convective turmoil characteristic of a hailstorm."

28. TREWARTHA, *op. cit.* *supra* note 15, at 290.

29. Durso, *When the Snow Flies*, New York Times Magazine, January 19, 1947, p. 22; New York Times, January 16, 1948, p. 1, col. 8. Failure to segregate such costs from other street sanitation in municipal reports makes statistics difficult to obtain, but an idea of the investments and expenditures involved can be had from Warner, *Pre-winter Snow Removal Plans: Detroit*, American City, October, 1945, p. 103; Osborne, *Buffalo, New York: Operation Snowball*, Traffic Engineering, January, 1947, p. 146.

30. New York Times, February 7, 1948, p. 14, col. 4. In transport, the Long Island Railroad suffered an added \$1,000,000 in operating costs not including freight and passenger losses, New York Herald Tribune, January 8, 1948, p. 25, col. 5, and airline and other schedules were disrupted.

31. As to this hastening process, see FIRST CIRRUS REPORT 9, and New York Times, November 15, 1946, p. 25, col. 6. Similar considerations would apply to rain, but in either case, if the storm is frontal or caused by other large scale conditions, operations would apparently have to be continued as long as protection were desired, in some cases for days. *Hearings before the House Subcommittee on Appropriations on Department of Commerce Appropriations Bill for 1948*, 80th Cong., 1st Sess., 93 (1947).

32. See Langmuir, *Cloud Seeding and Self Propagating Rain and Snow Storms*, re-

Although the next three years may see such diversionary techniques perfected on a small scale, it probably will be ten years before such knowledge can be applied in a general or practical way.³³ During the winter of 1946-7, residents of Buffalo requested General Electric Laboratories researchers to attempt this type of relief against snowstorms coming onshore from Lake Erie, but it was "felt that such large scale operations are properly functions of government."³⁴

HURRICANES. These tropical cyclones caused property damage amounting to \$150,000,000 in 1944, \$80,000,000 in 1945, \$10,000,000 in 1946 and \$135,000,000 in 1947—all in addition to considerable loss of lives.³⁵ The types of destruction, including that from gale winds, waves driven onshore, excessive rain and associated floods, are familiar. There is general agreement that the sustaining energy of the developed tropical cyclone is the latent heat released by condensation and precipitation occurring within it.³⁶ This fact raises the probability that nucleation techniques may, by modifying precipitation, dissipate incipient or possibly even developed hurricanes; or, by disturbing their equilibria, change their tracks. Refinements may make this technique practicable within one or two years.³⁷ An experiment in the effect of nucleation techniques upon a hurricane, conducted in 1947 by the armed forces' weather control research organization, Project Cirrus, will be discussed in detail later.

Water storage—drought alleviation

The portion of the United States lying west of the line Lake of the Woods—Rock Island—Kansas City—Galveston suffers from continuous, seasonal or occasional shortage of water supply from direct precipitation.³⁸ This means that much of the area is dependent upon

ported in *Aeron.Eng.Rev.*, April, 1948, p. 23. Only exhaustive field experiments could determine the extent to which the ground position of any part of a large scale disturbance could be changed. Attempts to induce snowfalls for recreational purposes are noted *infra*.

33. This summary of Langmuir's opinion at the sixteenth annual session of Institute of Aeronautical Sciences, January 29, 1948, is reported in *New York Times*, January 29, 1948, p. 25, col. 6. It will be shown later that "general or practical" application is unnecessary to raise legal questions.

34. Spencer, *The Man Who Can Make it Rain*, *Saturday Evening Post*, October 25, 1947, p. 24.

35. 74 *MON.WEA.REV.* 205, 215 (1946); 75 *id.* 251 (1947).

36. TANNHILL, *HURRICANES* 48 ff., 75-76 (2d ed. 1942).

37. Quoted in *Weather Under Control*, *Fortune*, February, 1948, p. 107.

38. Based on Thornthwaite's classifications. From the Pacific Coast to the crests of the Sierra-Cascade Barrier, the climate is summer-dry; thence east to roughly the 97th meridian it is continuously deficient in rainfall; and the interior subhumid states become dry or semi-arid in one to ten out of twenty years. See Thornthwaite, *The Climates of North America According to a New Classification*, 21 *GEOG.REV.* 633 (1931); *CLIMATE AND MAN* 171.

irrigation, where possible, from the humid islands within it.³⁹ Even a proportionately small water deficiency results in lowered agricultural production; and ten to fifteen percent below the norm means disaster for some areas. Damage done by major droughts is so great and so wide-spread as to be almost incalculable. One estimate of direct damage done to agriculture alone by the 1934 drought placed the figure at five billion dollars; the other hardships it caused are common knowledge.⁴⁰

Weather modification may help alleviate rainfall deficiencies by increasing precipitation (including snowfall in winter) within drainage areas equipped with storage facilities, thus permitting later distribution through irrigation systems.⁴¹ Increase of snow or water available for storage would also make possible fuller use of hydroelectric power plants; and diversion of precipitation to higher levels, where a downhill series of such plants exist, would allow multiplied use of its potential energy.⁴² The mountainous terrain features of such regions furnish an upslope lifting mechanism for cloud formation and continuous moisture supply, and also sites for the less expensive ground generator techni-

39. In the following states, proportions of irrigated farmland, by value, are: Nevada, 95 percent; Utah, 85 percent; Arizona, 75 percent; California, 70 percent; Colorado and Idaho, 65 percent. Detailed figures are given in 16TH CENSUS OF THE U.S.: 1940; IRRIGATION OF AGRICULTURAL LANDS (1943).

40. The most recent comprehensive work on this subject is Tannehill, *DROUGHT* (1947), which considers the possibility of precipitation control through the use of atomic energy; see also Hoyt, *DROUGHTS*, Ch. 12 in IX PHYSICS OF THE EARTH (Meinzer ed. 1942). It should be remembered that the quantities of water involved in such deficiencies are enormous.

41. FIRST CIRRUS REPORT 10-11. A demonstration of this application by Schaefer last summer was successful in producing some precipitation behind Roosevelt Dam. *Newsweek*, August 4, 1947, p. 64.

42. Switzerland has requested aid from the American scientists to carry out this type of use. Richards, *How to Make it Rain*, Country Gentleman, August, 1947, p. 18. The writer has been informed that experiments were conducted by the Swiss government during 1947. See also, *Hearings before the House Committee on Interstate and Foreign Commerce on H.R. 4582*, 80th Cong., 2d Sess. [hereafter referred to as *Simpson Bill Hearings*] 24 (1948). Opinion is in flux; cf. Reichelderfer's earlier letter to the editors, *Fortune*, March, 1948, p. 38. Visher, *op.cit. supra* note 21, asserts that a quantity of rain equal to that in an ordinary local thunderstorm may at times be worth millions of dollars. For small scale, mostly amateur, attempts in which some success was claimed in Arizona, Colorado, Hawaii, Illinois, Indiana, Iowa, Kansas, Louisiana, Missouri, Oklahoma, Oregon and Texas, see Life, Sept. 8, 1947, p. 53; Time, Sept. 1, 1947, p. 15; Readers Dig., Nov., 1947, p. 8; New York Times, Oct. 11, 1947, p. 20, col. 1; Aug. 20, 1947, p. 1, col. 2, Sept. 2, 1947, p. 25, col. 6; *Weather Under Control*, Fortune, Feb., 1948, p. 107, 111; Whitney, *Storm Over Rain*, New York Times Mag., December 14, 1947, p. 33, 35. Experiments have been made or projected in Africa, Australia, Cuba, India, Peru and Spain. Kraus and Squires, *Experiments in the Stimulation of Clouds to Produce Rain*, 159 NATURE 489 (1947); Time, Dec. 15, 1947, p. 41; New York Herald Tribune, March 17, 1948, p. 10, col. 2; 53 SCI.N.L. 45 (1948); Kansas City Times, July 8, 1948.

ques. As a result, interested persons in Washington and Oregon have shown a desire for continued experiments in these areas.⁴³

Prevention of freezing rain, sleet and glaze

Statistics on economic losses caused by these conditions do not seem to have been segregated, but their effects in hampering work, breaking wiring and increasing accident hazard in air, land and sea transportation and in urban and industrial areas, harbors and railroad yards are very sizeable. In farm areas, in addition to the temperature effects themselves, trees and shrubs are broken and overwintering crops are smothered and otherwise damaged by icing conditions.⁴⁴ Aircraft using nucleation techniques should be able to eliminate icing conditions in clouds at rates covering roughly 1000 square miles per hour, and nucleation of huge masses of air by silver iodide generators on the ground "would prevent all ice storms, all storms of freezing rain, and icing conditions in clouds" in a given area.⁴⁵ Icing conditions in fogs, which sometimes cause rime (ice-needle) formation on surface objects, could be similarly treated.⁴⁶

Cloud and fog dispersal

By reducing visibility, clouds increase accident hazards in air transportation, and fog likewise endangers and hampers land and sea transport. Supercooled clouds and fogs might be dispersed by nucleation techniques already described as well as by ground generator techniques. The utility of such cloud and fog dispersal may be demonstrated quite easily. The group of states lying north of the line Fargo-Nashville-Cape Cod receive only 50 per cent or less of their possible winter sunshine; parts of Wisconsin, Michigan, Ohio, Pennsylvania, New York, Vermont, New Hampshire and Maine receive only 30 per cent or less. This is largely due to their annual average of 120 to 180 cloudy days, plus an almost equal number of partly cloudy days.⁴⁷ Dispersal of clouds on a systematic basis in portions of this area "would change

43. FIRST CIRRUS REPORT 14; and see an address by Hovde, reported in St. Louis Post-Dispatch, December 17, 1947, p. 5B, col. 1. Reichelderfer, chief of U.S. Weather Bureau, has stated that "it is likely that artificially induced precipitation can be produced in quantities that would be very valuable," *Simpson Bill Hearings*, *supra* note 42 at 24. But *cf.* note 19 *supra*.

44. A single ice and glaze storm in Kansas on December 2-3, 1947, did \$3,000,000 in damage. 75 MON.WEA.REV. 239 (1947).

45. FIRST CIRRUS REPORT 10-11, 14-15. Compare Schaefer's statement in a radio address, November 7, 1947, that there was "good evidence that the serious ice storms of last winter resulted from the formation of rain in supercooled clouds. Under such conditions it should have been possible to convert all of this rain to snow." Reported in New York Times, Nov. 8, 1947, p. 3, col. 3.

46. See FIRST CIRRUS REPORT 27.

47. CLIMATE AND MAN 740, 742.

the albedo [degree of whiteness] and thus change the amount of heat absorbed from sunlight. It should be possible to change the average temperatures of some regions during the winter months."⁴⁸ Even a rather small temperature rise could decrease requisitions upon our tight supply of gas, oil and other petroleum heating fuels. Increase in light received would decrease electric power load for daylight illumination purposes.⁴⁹ And decrease of cloud cover at other points might increase growing seasons; at particular periods, it might even aid in control of plant diseases, insects and parasites.

Forest fires

Such fires cost \$26,000,000 or more each year and affect 17,000,000 acres of land. The Maine forest fires of October, 1947 did \$8,000,000 of damage at Bar Harbor and Kennebunkport alone, not including inestimable damage to forest lands, watersheds, wild life and timber lands.⁵⁰ Artificial precipitation techniques, in addition to their possibilities with regard to lightning, might produce rainfall to assist in bringing such fires under control.⁵¹ At the request of state authorities, Project Cirrus made one such experiment during the Maine fires;⁵² there were other official and unofficial attempts in 1947 and 1948 in which varying degrees of success were claimed.⁵³

Flood control

In the years 1923-44, flood-caused property losses in the United States averaged more than \$100,000,000 annually. No attempts at application of weather modification techniques to flood control problems have been reported, but the possibilities of moderating thunderstorms, or of diverting storms which threaten river basins already approaching flood stage make it clear that flood control should be included as a field of possible application.⁵⁴

48. FIRST CIRRUS REPORT 11.

49. See Schiller, *Daylight Illumination and Electric Supply Demand*, 161 ENGINEERING 158 (1946).

50. These were the 1945 figures. ANNUAL REPORTS OF DEPARTMENT OF AGRICULTURE, 1946, REPORT OF CHIEF OF THE FOREST SERVICE, TIMBER SHORTAGE OR TIMBER ABUNDANCE? 14, 21; New York Times, Oct. 23, 1947, p. 27, col. 3; St. Louis Post-Dispatch, Dec. 28, 1947, p. 14G, col. 2.

51. See testimony of Brown (Chief, Division of Fire Control, Forest Service, U.S. Department of Agriculture) in *Simpson Bill Hearings* 30-31, on the value of such assistance.

52. Participants claimed an increase in rainfall rate, and some increase was recorded, but local Weather Bureaus considered the results "inconclusive." New York Times, Oct. 30, 1947, p. 6, col. 3.

53. New York Times, Oct. 29, 1947, p. 1, col. 6; Time, June 21, 1948, p. 82.

54. See Brown, *Damages Resulting from Uncontrolled Runoff and Sedimentation*, 3 JOURN. OF SOIL AND WATER CONSERVATION 21 (1948), asserting that indirect damage

Military uses

Military applications of weather control are beyond the scope of this inquiry but the broad implications of any such control for atomic, bacterial and chemical warfare⁵⁵ are obvious. According to General Kenny, Commander of the Strategic Air Force, "the nation which first learns to plot the paths of air masses accurately and learns to control the time and place of precipitation will dominate the globe."⁵⁶

Concern with theoretical advances and possible applications should not be permitted to overshadow the ultimate objective of weather control, which is to render calculable the effects of any hypothetical human intervention—to introduce control as distinguished from haphazard interference. Considerable attention should therefore be focussed upon where and when the weather-control trigger ought to be pulled in order to produce the desired results.⁵⁷ Thus far, colloido-meteorological research has had greater success in supplying the trigger than in charting the results. It is precisely because of this inadequacy of information in regard to the growing storehouse of modification techniques⁵⁸

is much higher. See also White, *Economic Aspects of Flood Forecasting*, 20 TRANS. AMER. GEOPHYS. UNION 218 (1939); *Simpson Bill Hearings*, 32-34.

55. The subject can be pursued and references found to most of the recent declassified material in BALDWIN, *THE PRICE OF POWER* 69-75 (1948); COALE, *THE PROBLEM OF REDUCING VULNERABILITY TO ATOMIC BOMBS* 68-70, 93-98 (1947). It has been asserted that the other techniques are more deadly than the atomic bomb itself; see Barker, *Chemical Weapons of the Future*, *Military Review*, June 1947, p. 30-35 (suggesting guided long range missiles, drone planes and medium long range high capacity rockets as carriers to avoid the shielding problems called insuperable in popular accounts).

56. In an address quoted in *New York Times*, June 15, 1947, p. 46, col. 1. Bliven, *Death in the Air*, *The New Republic*, Feb. 2, 1948, p. 17; Glenn L. Martin, interview in *New York Times*, March 25, 1948, p. 6, col. 3; and cf. Lapp, *Atomic Bomb Explosions—Effects on an American City*, 4 BULL. OF THE ATOMIC SCIENTISTS 49, 52, 53 (1948). There has been speculation that the recent test by Joint Task Force Seven at Einewetok "might have been conducted in the air, and might have involved a cloud," *New York Times*, April 20, 1948, p. 1, col. 7.

57. Attempts are now being made to render meteorological conditions predictable by means of high-speed, automatic, electronic computing machines. Such an instrument is being constructed by the Institute for Advanced Studies, R.C.A. Laboratories, and the Army and Navy. When completed some months hence, this electronic computer will perform 100,000 mathematical operations per minute and make possible a completely calculated weather forecast for the entire northern hemisphere in two hours. See von Neumann, *Future Role of Rapid Computing in Meteorology*, reported in *Aeron. Eng. Rev.*, March 1947, p. 34; *New York Times*, Jan. 31, 1947, p. 16, col. 1; Note, 74 U.S. NAV. INST. PROC. 261 (1948). A general discussion of such computers can be had in Tumbleson, *Calculating Machines*, 67 ELEC. ENG. 6 (1948); and some of the mathematical calculations required by dynamic meteorology are illustrated by HAURWITZ, *DYNAMIC METEOROLOGY* (1941).

58. Among the techniques suggested, in addition to nucleation, are the application of atomic energy, modification of insolation by changing the absorption-radiation capacity of portions of the earth's surface, artificial heating, or use of ultrasonic vibrations. See

that legal problems have arisen and are even more likely to arise as experimentation continues.

THE RISE OF DISPUTES

The legal whirlwind followed fast upon the spate of weather modification attempts by amateurs as well as scientists. In many instances, these were carried on without recognition of the present impossibility of confining the effects to property owned by persons who were agreed on the desired conditions. Disputes were inevitable, and the size of the personal and economic values involved made it likewise inevitable that these disputes would become "legal" through appeals to the organized community for their settlement. Several have resulted in public threats of litigation in the fields of tort and property law and in one or two instances, actions have been filed.⁵⁹ Although each of this growing group of controversies has its own facets,⁶⁰ examination of a few of them will present enough generalized aspects to furnish a foundation for analysis.

On October 13, 1947, Project Cirrus conducted a nucleation experiment on a hurricane which was then located about 300 miles southeast of Cape Hatteras. By the night of the 14th, the hurricane, which had been moving off-shore, had reversed the direction of its movement. It entered the coast a short distance south of Savannah on the 15th, doing estimated damage of \$2,000,000 in the Savannah region and unestimated damage in South Carolina. Disputes soon arose about the relation between the nucleation and the hurricane damage but shortly thereafter, details of information on the matter were classified

Pastukh, *Kvoprosu ob energeticheskikh vosmozhnostyakh razrusheniia voln kholda* (On the question of the possibility of the destruction of cold waves by means of [atomic] energy), *Meteorologia i Gidrologia, Informatsionnyi Sbornik* [hereafter *Met. i Gidr.*] No. 2, p. 16 (1946), as abstracted in 28 *BULL. AMER. METEOR. SOC.* 432 (1947); Zworykin, *Discussion of the Possibility of Weather Control*, reported in *Aeron. Eng. Rev.*, February 1947, p. 26; *New York Times*, Jan. 31, 1947, p. 16, col. 1; 28 *BULL. AMER. METEOR. SOC.* 334 (1947); *Aviation Week*, Aug. 11, 1947, p. 15; Manchester, *Strange New Uses of Sound*, *Atlantic*, Sept. 1947, p. 54; 49 *SCI. N. L.* 276 (1946). Ultimately, some combination of methods may prove to be the best means of control.

59. *Simpson Bill Hearings* 26-28. There have been press reports of litigation in California and Kansas. *New York Times*, Jan. 18, 1948, sec. 4, p. 8E, col. 2. Files were not available to the writer, but in the latter state, an injunction is said to have been granted in the District Court, Reno County, against defendants alleged to be preparing to induce rain during the pendency of the State Fair. Plaintiff is later said to have written a letter stating that "the whole thing was a publicity proposition for the State Fair." *St. Louis Globe-Democrat*, April 1, 1948, p. 4A, col. 1. If accurate, this leaves the litigant and the trial precedent in a status which is interesting, but beyond the scope of this article.

60. For other examples, see *Simpson Bill Hearings* 28; *New York Sunday News*, Jan. 18, 1948, p. 6. (claim that attempts at drought relief injured date crop requiring dryness at that time); *New York Times*, August 14, 1947, p. 48, col. 6. (threat of injunction against artificial precipitation during baseball series); August 31, 1947, sec. 4, p. 8, col. 4 (claim that drought relief attempts interfered with urban heat relief).

by the Department of National Defense as military secrets, and continued for some time in that status. Attempts have been made to explain the event, but a final answer must await release of the remainder of the observational data and photographs.⁶¹ The lesson to be learned, however, is quite plain: the artificial deflection of a hurricane might well result in a considerable number of claims for personal injury and property damage.

The second type of problem may be quickly indicated. There is currently pending in the office of the State Engineer of Nevada an application by a ranch owner, based upon the state water rights statute,⁶² to appropriate water at the rate of 1000 cubic feet per second from all clouds which may pass over the ranch. In the same area, attempts to produce snow in Nevada for ski meets have resulted in charges of illegal water diversion and threats of litigation from Utah. Both attempts and threats began as publicity stunts, but tended to take on a more serious aspect because of the severe droughts in the region.⁶³

In general, two classes of disputes are likely to arise out of attempts at weather modification: claims for personal injury and property damage alleged to have been caused by the modification; and claims of property rights in the weather, or in some particular elements of weather phenomena. Apprehension of such claims has existed almost from the beginning of experimentation, and has been growing since. Before entering into the Project Cirrus contract, General Electric Company attempted unsuccessfully to have an indemnity clause inserted. In their very first report, the company's researchers had counselled that experiments which were likely to have widespread effects "should be made in relatively unpopulated regions such as Alaska or

61. See Langmuir, *The Growth of Particles in Smokes and Clouds and the Production of Snow from Supercooled Clouds*, 92 PROC. AMER. PHILOS. SOC. 167, (1948); Miami Herald, October 21, 1947, p. 13A, col. 1; October 31, 1947, p. 1A, col. 1; *Simpson Bill Hearings* 20, 25. In the article cited above, Dr. Langmuir quotes (at 184-5) an eye witness account prepared by Commander Rex, Chairman of the Operations Group of Project Cirrus. This very short report states that seeding at the most desirable points was prevented by failure of the aircraft's homing aids (radio compass and visual flares), but that an area of about 300 square miles was modified. Dr. Langmuir concludes: "They felt however that if they could have been on the other side of the squall line, which I already mentioned, some really important things might have happened. What did happen, nobody knows."

62. NEV. COMP. LAWS (Hillyer 1929) §7890: "The water of all sources of water supply within the boundaries of the state, whether above or beneath the surface of the ground, belongs to the public." §§7944 *et seq.* provide the procedure for appropriation by individuals.

63. See New York Times, Jan. 18, 1948, sec. 4, p. 8E, col. 2. The qualification is indicated in a communication to the writer from Hon. Grover Giles, Attorney General of Utah, dated April 6, 1948.

Northern Canada";⁶⁴ by September 14, 1947, their opinion was that "before any experiments are conducted, prevailing weather conditions in the immediate area should be analyzed carefully by a competent meteorologist";⁶⁵ and on the 19th, "Unqualified persons may produce extremely disastrous results which science knows nothing about unless extreme care is exercised. . . . Science is only beginning to scratch the surface of this question, and experiments in it should be carefully controlled."⁶⁶

After the hurricane experiment described above, it was reported that General Electric had stopped all outdoor experimenting. Its Director of Research stated that "until the legal problems are clarified, there will be great difficulty in carrying out large-scale experimentation."⁶⁷ And press dispatches on August 12, 1948 stated: "Earl Droessler, member of the Cirrus steering committee, says the scientists will leave hurricanes strictly alone this summer."⁶⁸

LEGAL ANALOGIES

"This odd legal vacuum, caused by science,"⁶⁹ will scarcely continue. Law, like nature, abhors a vacuum. Courts, with or without legislative and administrative assistance, will be called upon to chart the fields of alleged responsibility and ownership.⁷⁰ In part, the parameters they draw will be the result of their matching these problems with others already resolved; therefore, an indication of concepts which lie at hand is in order. Liability might be imposed upon those engaging in weather-control⁷¹ activity by application of any of several familiar doctrines of tort or criminal law, as well as under statutes already widely in force.

Consider the hypothetical case of a private individual, A, who, by dispensing dry ice from an aircraft without notice or useful purpose,

64. FIRST CIRrus REPORT, 11 (covering only to July 15, 1947).

65. Schaefer's view, reported in *New York Times*, Sept. 14, 1947, pt. iv, p. E 9, col. 7.

66. Schaefer, in an address reported in *New York Times*, Sep. 20, 1947, p. 17, col. 2.

67. *Time*, December 22, 1947, p. 44. An earlier effort at insulation from possible liability had taken the form of prohibition of any employee's actually releasing nucleating materials from a plane; and see Chambers' statement, *Simpson Bill Hearings* 14. This question is discussed in subsequent sections.

68. *Dallas Morning News*, Aug. 13, 1948, p. 4, col. 1.

69. *Time*, Dec. 22, 1947, p. 44.

70. Cf. Chambers' testimony in *Simpson Bill Hearings* 13. As early as 1894, Harrington had said: "Should the weather maker prosper, he will often find himself very much harassed until our lawmakers have caught up with our advance in the arts, and the volume of the statute books has been materially increased." Harrington, *Weather Making, Ancient and Modern*, *Nat. Geog. Mag.*, April, 1894, p. 35, 48.

71. The primary elements of atmospheric condition here relevant are (a) temperature, (b) winds and air pressure, (c) humidity, and (d) hydrometeors, including all forms of precipitation and such phenomena as lightning. All that we call weather can be expressed by some combination of these elements.

causes a developing storm system moving at twenty miles per hour to precipitate snow some hours and miles before or after it would otherwise have done—thereby affecting an urban and industrial area of twenty square miles.⁷² While it is snowing, a number of motor accidents occur, substantially contributed to by the reduced visibility and attended by personal injury and property damage; the snow cover impedes traffic and hinders outdoor work, resulting in lost production; and several persons are injured in falls on the insecure footing of the sidewalks.

Criminal prosecution and similar statutory penalties

In such a case, *A* might be prosecuted (or enjoined) for creating a public nuisance by obstructing the highways, or for assimilable statutory offenses.⁷³ In addition, the aircraft might be seized and impounded, a civil penalty recovered, and the pilot's certificate suspended or revoked for violating the Civil Air Regulations which specify that "no person piloting an aircraft shall permit anything to be dropped from an aircraft in flight which might create any hazard to persons or property."⁷⁴ Similar statutes or regulations exist in a number of states and some have provided that violation thereof is a misdemeanor.⁷⁵

Tort liability

Theories which might be urged to prove civil liability (including liability to be enjoined) would include absolute liability for trespassory invasion of real estate (including purpresture),⁷⁶ permitting recovery of at least nominal damages (under many decisions) by all owners of

72. This is well within the results obtained in the Cloud Physics Project tests, Time, Dec. 6, 1948, p. 50. Use of atomic energy or other proposed methods would produce similar types of modifications and all would probably involve dispensing materials from aircraft.

73. See, e.g., N.Y. PENAL CODE § 1530; ILL. CRIM. CODE § 466; *Davis v. Spragg*, 72 W.Va. 672, 79 S.E. 652 (1913). It has been held that neither intent nor actual damage are elements of the crime.

74. 14 CODE FED. REGS. § 43.408 (Supp. 1945), issued under the Civil Aeronautics Act, 52 STAT. 973 (1938), as amended, 49 U.S.C. 401 (1946). For the impounding procedure, see Regulations of the Civil Aeronautics Administrator, 14 CODE FED. REGS. § 531.1 (Cum.Supp.1943).

75. ARIZ. CODE, § 48-115 (1939); Ind. Laws 1947, c. 42; N.C. Laws 1947, c. 1002; cf. Wis. Laws 1947, c. 213, and Okla. Laws 1947, Title 3, c. I(a), which makes careless flying unlawful and key "careless" to the Federal regulations.

76. An Opinion of the Attorney General of Minnesota, January 15, 1948, holds that when drift from aerial crop-spraying is carried to neighboring fields a trespass is committed. 2 C.C.H. AVI. LAW SERV. ¶20,038 (1948). The orthodox rule is stated and authorities given in PROSSER, TORTS § 13 (1941); HARPER, TORTS § 37 (1933); cf. RESTATEMENT, TORTS § 158 (1934). On purpresture, see *Davis v. Spragg*, 72 W. Va. 672, 673-4, 79 S.E. 652, 653 (1913). The snow might easily remain long enough to satisfy the requirement of permanence.

possessory interests whose land or effectively tenable airspace had been entered by the snow; absolute liability for harm caused by the operation of an ultrahazardous activity,⁷⁷ permitting recovery for all the harms described; absolute liability for all harm caused to persons or property on the ground by operation of an aircraft, under Section 5 of the Uniform State Aeronautics Law⁷⁸ or similar statutes in force in many states; liability for negligence in conducting the activity without taking the precaution of giving warning and otherwise creating an unreasonable risk of harm to persons and property on the ground,⁷⁹ permitting recovery for all the harms described;⁸⁰ liability for nuisance, based on intention, negligence or the carrying on of the activity in an unreasonably unsuitable locality, permitting recovery for the cost of lost production, snow removal, and other harms which took the form of substantial interference with the use and peaceable enjoyment of the owners' land and airspace.⁸¹

77. RESTATEMENT, TORTS §§ 519-520 (1938).

78. 11 UNIF. LAWS ANNOT. 161 (1938). On the question when the damage is too remote from the operation of the aircraft, a glossator has said that this section would make the owner liable for damage done by bombs dropped from a stolen plane by a thief, or when an unpredicted storm strikes down the ship. Reiber, *Some Aspects of Air Carriers' Liability*, 11 LAW AND CONT. PROB. 524, 528-5 (1946).

79. As to notice and other precautions, see generally, RESTATEMENT, TORTS §§ 181, 183 (1934). In *Skeels v. U.S.*, 72 F.Supp. 372 (W.D. La. 1947), a complaint construed as alleging that the Army was engaged in target practice with its military planes six miles out in the Gulf of Mexico; that a piece of pipe fell from the aircraft or the targets striking plaintiff's decedent; and that there was negligence in carrying on such activities without establishing a restricted area and giving notice, was held sufficient against a motion to dismiss. *Lundberg v. Bolon*, 67 Ariz. 259, 194 P.2d 454 (1948) seems to question whether defendant, engaging in aerial crop-dusting which caused the death of plaintiff's bees, could be found negligent in failing to give notice of the operation. For another crop-dusting case, see *Miles v. A. Arena and Co.*, 23 Cal.App. 2d 680, 73 P.2d 1260 (1947).

80. As to the injuries caused by falling on the public ways, see *Diehl v. Fidelity Philadelphia Trust Co.*, 159 Pa. Super. Ct. 513, 49 A.2d 190 (1946), a case which comes close to artificial precipitation. Steam coming from a vent in defendant's building condensed because of a cold wind and fell, forming a coating of ice on the pavement adjoining another defendant's property; both defendants had notice that this was happening. The conduct of each was held a proximate cause and both were held liable for negligence to one who fell on the ice. See, also, *Hooper v. Kennedy*, 320 Mass. 576, 70 N.E.2d 529 (1947); *Stith v. Newberry Co.*, 336 Mo. 467, 79 S.W.2d 447 (1934). As to the liability for traffic accidents, see *La Velle (Hudson) v. Grace*, 348 Pa. 175, 34 A.2d 493 (1943), in which defendant was held liable for allowing steam to escape over a highway, obscuring vision and causing an auto collision. *Accord*, *Oviatt v. Garretson*, 205 Ark. 792, 171 S.W.2d 287 (1943) (smoke from brush fire purposefully set by railroad employees).

81. The surface owner's remedy for wrongful use by others of the upper air stratum which he may not reasonably expect to occupy is ordinarily an action for nuisance, *Swetland v. Curtiss Airports Corp.*, 55 F.2d 201 (6th Cir. 1932). In this aspect, inducing changes in the atmosphere may be considered a form of air pollution, as to which see *Runkle, Liability for Nuisances Resulting from Atmospheric Pollution*, 12 INS.COUNSEL J.. No. 1, 45 (1945).

Discovery, proof and causation

Some major difficulties with the foregoing analysis lie in another quarter. In view of the distances at which effects may occur, the putative plaintiff is extremely unlikely ever to discover even the fact of the weather-modification activity. Nor is this his only hurdle. The dean of British meteorologists has said that "Every theory of the course of events in nature is necessarily based upon some process of simplification of the phenomena and is to some extent therefore a fairy tale."⁸² For some time, one of the most difficult questions which will be before courts in these cases, if indeed it succeeds in reaching them, is the question of "causation in fact."

Proof of what happened during a weather modification attempt will represent an effort to reconstruct the flow of events in an air column whose volume may range up to thousands of cubic miles, inclined at varying angles from the earth's surface and moving at speeds ranging up to forty or more miles per hour. Major transformations will always be in process—being accomplished by invisible air movements and by such hard-to-measure factors as pressure, temperature, humidity and the actions of submicroscopic colloidal particles. The most intensive and extensive instrumentation so far used has left the precise effects of nucleation techniques in specific instances a matter of some doubt, at least so far as declassified and published data and opinions are concerned.⁸³ In the many amateur efforts, all that can be presented are scanty pictures of temporal succession. Such inadequate descriptions might have to multiply for years before rudimentary, empirico-intuitive assertions of necessary connections could be made on a statistical basis.

Judges' rules of thumb for spanning such gaps in evidence of causation have been developing for centuries, using amorphous statistics winnowed from a vast vague harvest called "human experience." From time to time, aid has been drawn from a body of theoretical explanations which frequently require far more data than can be un-

82. Sir Napier Shaw, in 1 *MANUAL OF METEOROLOGY* 23 (1933).

83. Some notion of what is needed can be had from *FIRST CIRRUS REPORT*, Part IV: Instrumentation Developed for the Cloud Study Project, listing (in addition to standard aircraft instruments, aerograph, cameras, dry ice dispenser and silver iodide generator) the icing rate exposure rod, clinometer attachment for camera, wire recorder, cloud (liquid water content) meter, exposure gun and air decelerator, and altimeter and elevator position recorder; and Part VIII, Proposed Flight Plans, emphasizing the need for simultaneous use of three aircraft (radar equipped), a complete photographic record (color, infra-red, stereoscopic and polarized filter) at the rate of one picture per minute, and other records synchronized to the second with such flight data as heading, altitude, airspeed and temperature. The Weather Bureau has found a very dense network of ground observation stations (observers not over a mile or two apart) and precipitation recorders, plus radar scope photographs, necessary to scientific precision in its weather modification experiments.

covered in the ordinary lawsuit and which are themselves subject to change when new fields are involved. In the present situation, there is no experience; and the most sanguine theoreticians do not claim that scientific explanations can be adequate where almost none of the information needed is likely to be gathered unless some prior legal requirement to that effect is imposed.⁸⁴

In the past, courts confronted with such mysteries have eventually forced a trial balance by deciding that *res ipsa loquitur*. Useful as this concept may be in other contexts, the length of time needed for it to approach resolution of the present problem can be gleaned from its history in the field of air transport, which is apposite because it involves the interaction of humanly controlled agencies and atmospheric conditions. In the last half century, private, commercial and military aviation has assumed gigantic proportions; but courts are still not able to locate a sufficient fund of "common" experience to make possible inferences or estimates of probabilities as to weather effects on the behaviour of aircraft and their operators.⁸⁵

The reason for this inability seems obvious: it lies in the nature of the activity and in its conditions; the difficulties will be even greater in the case of weather modification operations.⁸⁶ Advances in dynamic and descriptive meteorology of the sort already referred to will in time resolve doubts, as they must if control is to be completely rational; but only in the presence of exhaustive instrumentation, observation and record-keeping can "what happened" be reconstructed. The pressing

84. Such requirements have been found necessary in state regulation of aerial crop-dusting operations. See, e.g., Idaho Session Laws 1947, c. 264, empowering the state Commissioner of Agriculture to control such activity; regulations require, *inter alia*, a license, that the operator keep informed as to proper climatic conditions and refrain from spraying when wind velocity exceeds ten miles per hour, use of insecticides of certain weights, timing of operations so as not to endanger pollinating insects, bees or livestock, and the keeping of complete records. Conn. Supp. to Gen. Statutes, § 842i, (1947), makes it a crime to engage in crop dusting without permit and waiver of state aeronautics regulations. Cf. Minn. Laws 1947, c. 560 (Commissioner of Agriculture to regulate and issue permits for insect control operations by aircraft); Wis. Laws 1947, S.B. 458 (regulation of crop dusting over forest and non-crop areas).

85. The latest of the considerable literature on this subject seems to be O'Connor, *Res Ipsa in the Air*, 22 IND.L.J. 221 (1947). See also RHYNE, *AVIATION ACCIDENT LAW* c. 8 (1947); Goldin, *Doctrine of Res Ipsa in Aviation Law*, 18 So.CALIF.L.R. 15 (1944); Harper, *Res Ipsa Loquitur in Air Law*, 1 AIR L.R. 478 (1930). A full-length treatment of the doctrine as a whole is found in SHAIN, *RES IPSA LOQUITUR* (2d ed. 1947).

86. Some evidentiary problems have already been noted. Another, with reference to the doctrine of *res ipsa*, is that it may not be invoked to prove that an instrumentality caused any particular result—the crucial question at the moment. *Holloway v. Skelly Oil Co.*, 68 F.Supp. 129 (E.D.Mo. 1946). Further, if an analogy to water flowage torts were to be chosen, plaintiff would be required to show how much of his damages are attributable to defendant's conduct and how much to natural causes for which defendant is not responsible—in a context where the two are likely to be inextricably blended. Note, 112 A.L.R. 1084 (1938).

legal task in the meantime is to permit development and, at the same time, to avoid or at least identify and adjust losses which all agree are likely to occur.

In this connection, a further difficulty may be noted. The consensus of those who have examined the possibilities of loss and liability is that they may easily amount to millions of dollars for a single miscarriage of the operations; *a fortiori* where elaborate precautions are not taken. In a situation where the only capital equipment required to cause such damage is an airplane, a quantity of granulated dry ice or the equipment for some other technique and a desire to do something about the weather, it seems inevitable that a judgment representing even the strictest of civil liability will be too often merely an empty declaration which effects no actual redistribution of incidence.

Conduct of the activity by government, its contractors or permittees

Some of the rules adduced will ultimately depend not only upon the manner and location of the activity, but upon who conducts it and with what purposes. Imposition of liability is progressively less stringent, even to the point of allowing immunity, as the activity is found to be socially valuable, or "public" in the sense of a formally authorized function of government; and the same would be true when the activity is carried on by the permittees or contractors, or employees and officials of government. Thus, the traditional legal doctrines of preemption and public nuisance relax where the temporary obstruction of the public way is for a public purpose;⁸⁷ inapplicability or waiver of aeronautics regulations would obviate the penalties there prescribed;⁸⁸ the rule of ultrahazardous activity is said not to apply where governmental sanction shows the conduct to be reasonable despite imminent risks;⁸⁹ the utility and social value of the activity would dispel most of the charges of private nuisance;⁹⁰ and the argument for treating technical trespasses as accidental intrusions, not entailing liability,⁹¹ gains force in such public activities.

But the extent of this insulation varies, and is by no means certain even as to given acts or actors. In addition, under the recent Federal Tort Claims Act,⁹² the defendant who seeks to avoid liability by way of

87. *Brey v. Rosenfeld*, 48 A.2d 177 (R.I. 1946); *Rief v. Mountain States Tel. & Tel. Co.*, 63 Ida. 418, 120 P.2d 823 (1941).

88. Civil Air Regulations, Part 60, 12 FED. REG. 5547 (1947); *cf. State v. Dickens*, 183 P.2d 148 (Ariz. 1947).

89. RESTATEMENT, TORTS § 521 (1938).

90. For this tort view as it has been applied to land and water nuisance problems, see RESTATEMENT, TORTS §§ 825-827, 841-864 (1939).

91. This effort to get away from the strict view is adopted in RESTATEMENT, TORTS § 166 (1934).

92. 60 STAT. 842 (1946), 28 U.S.C. § 921 (1946).

government's protective cloak is met by a statute which heads the other way and, in general, keys government liability to that of the private person. However, the extent to which this act can be urged as declaring a new view of the social value of government-sponsored conduct is at present unknown; courts have not yet had time to plot vectors for these seemingly convergent policy notions.⁹³

Security restrictions

If, as is possible, weather modification activity is conducted only by the Federal Government and its contractors, adequate instrumentation, observation and record-keeping is likely to be had. But persons who suffer harm would probably encounter another type of difficulty—that of discovering that a basis for a claim existed, or what that basis was.⁹⁴ The Army Regulations (and similar Navy Regulations) impose security restrictions on classified data, the applicable provision specifying that information,

“ . . . the unauthorized disclosure of which, while not endangering the national security, would be prejudicial to the interests or prestige of the nation, or any governmental activity, an individual, or would cause administrative embarrassment or difficulty, or be of advantage to a foreign nation shall be classified confidential.”⁹⁵

A threatened flood of lawsuits or claims for administrative attention could conceivably be fitted within this framework and be considered prejudicial to the nation or a governmental activity.⁹⁵ Possible liability

93. The short statute of limitations contained in the Federal Tort Claims Act will, of course, leave situations in which the contractor might remain liable while action against the Government has been barred.

94. The following is quoted from 25 CHEM. AND ENG.N. 3050 (1947), published on October 13, 1947: “G.E. attorneys report that they have already been threatened with damage suits where citizens suspect they had a hand in adverse weather. The Army's solution of the problem would be to classify all weather experiment information as ‘confidential’ or ‘secret.’”

95. The Army's rules are AR 380-5 (1946); the Navy's, NR 76 (repr. 1941) and Change 25 (1944). With reference to disclosure of information connected with a possible claim against the United States, see AR 25-20, par. 15 (1945); NR Art. 113 Change 26 (1945). The 1946 amendment to the Civil Aeronautics Act of 1938, 60 STAT. 944, 49 U.S.C. 603 (1946), authorizes the Chief of the Weather Bureau to provide for publication of the results of research under the Section “unless such publication would be contrary to the public interest.”

96. On the general subject see Baldwin, *The Problem of Secrecy*, N. Y. Times, March 5, 1948, p. 3, col. 6; cf. Newman, *Control of Information Relating to Atomic Energy*, 56 YALE L.J. 769 (1947). The official attitude to be taken seems not completely settled; compare the following quotations. Lee (Chief of Naval Research), Office of Naval Research, 39 MIL. ENG. 112, 113 (1947): “four freedoms emphasized in the Navy's ‘partnership agreements’ with scientists and scientific laboratories, it is believed, are conducive to the creation and dissemination of knowledge. These are . . . 3. Freedom of the scientist to publish the findings of his work on the premise that new knowledge of

has been averted for like reasons before, as in the case of some exceptions in the Federal Tort Claims Act; and immunity is one of the possible alternatives in the present instance. If any recovery is to be generally allowed for harm caused by weather modification experiments by government or its contractors, and in some or most instances, purely military considerations dictate nondisclosure, a method of administering the risk without public litigation is needed.⁹⁷

Claims of property in weather phenomena

That the effects of weather modification may give rise to conflicting property claims has already been indicated in a prior section. Invoking "water rights" doctrines, the disputants in those situations asserted, in one instance, a right to "appropriate" cloud moisture, and in another, a right to prevent its "illegal diversion." In a survey like the present one, there is space for only the briefest sketch of applicable legal analogies—a crude precis which must cover the country, for although these claims were made in or among "appropriation" states, similar contentions could be made anywhere.⁹⁸

WATER RIGHTS. Treating the atmosphere as an available source of water, the claimant has a choice among doctrines. Taking a rather weak analogy to streams, he may, in some eastern states, assert the "natural flow," or so-called English rule: that he shall receive the endless stream of air in its natural state, and, seemingly, thereby put an end to technological progress in this direction. In other states, where

natural phenomena is inherently free; . . ." Report of the President's Air Policy Commission, Official Summary, Sec. III (1948): "The commission believes that rigid enforcement of wartime security measures with respect to advanced aeronautical development is necessary." Cf. Report of the President's Scientific Research Board, Part II (1948).

97. Haydock, *Evidentiary Problems and Atomic Energy*, 61 HARV.L.REV. 463 (1948); Comment, 19 TENN.L.REV. 477 (1946). A recent case on the question of the court's power to pass on the claim to secrecy in a lawsuit is *Zimmerman v. Poindexter*, 74 F. Supp. 933 (D.Haw. 1947). One question not yet treated by the writers is whether the one-year statute of limitations of the Tort Claims Act runs if a prospective claimant is unable to learn about the facts because of security restrictions. Such information is difficult to come by even absent restrictions, as the law has recognized. Art. 17 of the Rome Convention of 1933, covering ground damage by aircraft in international transportation, proposed deferring the running of limitation for up to three years, where claimant could show his inability to learn the facts or the identity of the person liable. DEPT. OF STATE TREATY INFORMATION BULL. No. 47, p. 32 (1933); cf. *Tom Reed Gold Mines Co. v. United Eastern Mining Co.*, 39 Ariz. 533, 8 P.2d 449 (1932) (subterranean trespass).

98. For a comprehensive collection of the literature on which the following paragraphs are based, see McDUGAL AND HABER, *PROPERTY, WEALTH, LAND*, c. X (1948), pointing out the "property" problems; on particular phases, HUTCHINS, *SELECTED PROBLEMS IN THE LAW OF WATER RIGHTS IN THE WEST* (U.S. Dept. of Agriculture 1942); NATIONAL RESOURCES PLANNING BOARD, *SUMMARY OF THE STATUTES AFFECTING WATER IN THE 31 EASTERN STATES* (1940).

the somewhat abstract "correlative rights" or reasonable use rule obtains, he may demand that the courts begin the process, certain to be long and difficult, of translating those terms into the weather field, and thus raise in another form the problems of discovery, proof and causation already discussed. In the western states (including the two involved in the examples given), he may assert that by compliance with statutory formalities, he obtains a "right" to the use of the atmosphere superior to that of later applicants and appropriators; that right, once ripened, is conclusive against all but the police power and eminent domain.

But the rules which are most likely to be urged as analogous are those relating to so-called diffuse surface and percolating subsurface waters, in which early failure to recognize the interdependence of water sources has resulted in giving the landowner rights of conflict-breeding breadth. He may capture such waters in well or ditch; this makes him an "artificial producer" of water, and it becomes his "property," with all the incidents thereof, so long as he can hold it. The argument will run that he may do the same with moisture passing through his airspace.

When the question is one of diverting undesirable weather onto someone else, there is still another set of rules to invoke—those of water disposal. The diverter may describe the activity as part of a fight against the "common enemy"—water; the unwilling recipient will reply that nature must be allowed to take its own course under the civil law rule, drawing in a plethora of conceptions of "servitudes" with Latin names;⁹⁹ and both sides may argue that the third available view, that of reasonable use, coincides with their own contentions. At present, the jurisdictions are divided among all three views, a compartmentalization which the effects of weather modification are certain to span.

The foregoing is greatly oversimplified; almost every state has superimposed upon the basic rules decisional or statutory modification forced by pressures of conflict and confusion, and more or less in accord with advances in knowledge. Gradually, these have tended to take the form of continuing administration of water supply in the public interest.¹⁰⁰ In the interstate field, which is being increasingly recognized,

99. *Martin v. Simpson*, 6 Allen (Mass.) 102 (1863) discusses the *stillicidium*, or right to have water discharge in drops, and *flumen*, or right to have it flow. The servitude to have air flow unimpeded for windmills seems to be referred to in *State ex rel. Crowley v. Dist. Court*, 103 Mont. 89, 101, 88 P.2d 23, 28 (1939). Such rules apply only between adjoining landowners.

100. Lasky, *From Prior Appropriation to Economic Distribution of Water by the State—via Irrigation Administration*, 1 ROCKY MT. L. REV. 161, 248, 2 *id.* 35 (1929). Black, *Basic Concepts in Ground Water Law*, 39 AMER. WATER WORKS ASSOC. J. 939 (1947).

the Supreme Court has applied its own rule of "equitable apportionment," also urging interstate compact and administration.¹⁰¹

APPLICABILITY TO WEATHER PHENOMENA. Maugre all this willingness to cut and try, enough substantive rules of property in water remain to furnish ammunition even for arguments about the weather. Any or all of the doctrines could be urged as analogous, especially that of the "artificial producer."

It would seem more desirable, however, to reject substantive property analogies. The history of water law, like that of airspace ownership, oil, wild life, and even of radio's ether, is a story of a first cyclopean focus on things,—and a final realization of the inadequacy of reified concepts of property, or of rules of capture, as guides for umpiring disputes between men about complex practices.¹⁰² Claims of "property" are mere shorthand for arguments that the claimant is to be protected or left undisturbed in a very wide range (the widest known to the law) of practices related to a physical phenomenon. In new and uncertain fields, what is needed is a *modus operandi* permitting careful breakdown of problems, not a shorthand which obscures them by assuming the existence of knowledge, of precision and of the suitability of ready-to-wear principles fabricated in other contexts. The problem is primarily one of the development of certain techniques by which effects, both beneficial and harmful, may be produced—effects which will transcend the importance and boundaries of the varying sets of water doctrines. Weather modification techniques operate under conditions which are even more wandering and widespread. They are identifiable largely in terms of scientific postulations—to assert property in hydrometeors or other atmospheric elements is almost on a par with claiming the planets and galaxies which, as the earth turns, pass into the landowner's hypothetically infinite but recently much riddled funnel of dominion.¹⁰³ If development can be continued and more data

101. *Nebraska v. Wyoming*, 325 U.S. 589 (1945).

102. The conservation of natural resources has been the conceptual bridge to what results have been accomplished in the matters of water, minerals and game. As to airspace, the possible effect of such cases as *Causby v. U.S.*, 328 U.S. 256 (1946) should be considered. If long continued, would weather modification be a "taking" of an easement? In the radio field, the analogy to water rights was attempted, *Tribune v. Oak Leaves Broadcasting Station*, Circuit Ct., Cook County, Ill., Gen. No. B-136,864, 68 Cong. Rec. 216 (1926); Taugher, *The Law of Radio Communications with Particular Reference to Property Right in Radio Wave Length*, 12 MARQ.L.REV. 179, 299 (1928). Its eventual failure was inevitable. Segal and Warner, "Ownership" of Broadcasting "Frequencies": a Review, 19 ROCKY MT.L.REV. 111 (1947); cf. Otterman, *Some Legislative Aspects of Radio Control*, 20 TEMP.L.Q. 73 (1946).

103. SAUZE, LES QUESTIONS DE RESPONSABILITÉ EN MATIÈRE D'AVIATION 23 et seq. (1916), quoted in Bouvé, *Private Ownership of Airspace*, 1 AIR L.REV. 232, 246-7 (1930). The *ad coelum* rule of ownership seems generally rejected now. *Chi. & S. Air Lines v. Waterman S.S. Corp.*, 333 U.S. 103, 107-8 (1948).

become available, adequate organs and guides for the administration of those techniques and their effects can be fashioned. In the words of the Chief of the Weather Bureau, "the legal slate is still clear."¹⁰⁴ Certainly the law can do better than merely to copy upon it the mistakes of the past.

PRELIMINARY ANALYSIS AND PROGRAM OF ACTION

Current views on how the problems of law and policy raised by weather control should be answered are scanty and hard to combine. One position is that legislation would be premature and, seemingly, that what should come next is a great deal of litigation—to allow the common law to work out judicial policy.¹⁰⁵ Another is that litigation would be premature in that it would tie up experimentation;¹⁰⁶ and the third is, more inclusively, that no further field experimentation is feasible until the legal cloud has been cleared by legislating the matter into the hands of a new organ of administration.¹⁰⁷ The result is a three-horse carousel whose rotations must somehow be transformed into forward movement. The preliminary analysis and suggested steps which follow are presented as one means of breaking the current impasse.

That experimentation and research in the modification and control of weather will continue until its possibilities are fully explored, and that legal obstructions must somehow be removed, are virtually certain.¹⁰⁸ The unsuitability of ocean areas for most experiments, and the delay, expense and other logistic difficulties involved in constructing, manning and servicing the necessary elaborate facilities in remote locations mean that the research will be conducted in large part in the United States. But not enough is yet known about the factual possibilities of existing and future modification techniques to permit permanent selection of agencies and standards for the administration of their use.

104. *Simpson Bill Hearings* 28.

105. Editorial, "Trouble for Weather Makers," N. Y. Times, May 8, 1948, p. 14, col. 3, based on an editorial in the Harvard Law School Record.

106. This was the Weather Bureau's view, *Simpson Bill Hearings* 28; and also the view of those involved in the hurricane experiment.

107. This was urged by one witness in *Simpson Bill Hearings* 37; cf. report of the Secretary of Agriculture on H.R. 4582, *ibid.* 1.

108. If not in this country, perhaps in others; the projects in Canada, S. America, Spain, Cuba, Australia, India and elsewhere have already been noted, and see Fedorov, (Chief of the Hydrometeorological Service, U.S.S.R.) *Osnovnye Problemy Gidrometosluzhby* (Basic Problems of the Hydrometeorological Service), Met. i Gidr. No. 6, p. 3 (1946), as abs. in 28 BULL. AMER. METEOR. SOC. 474 (1947), on that country's plans for weather control research.

Temporary prevention of irresponsible activity

Until such an agency is formed and the necessary information amassed, it is an absolute "must" that these techniques or others like them should be practiced only by persons and organizations possessed of the scientific skills and facilities required for expert analysis of pre-existing meteorological conditions, and careful utilization and detailed recording of results. Otherwise, considerable damage to persons and property may result—in a way and on a scale which make redress through civil liability formally difficult and practically ineffective unless the actor is eminently solvent; all without producing any appreciable benefits in increased scientific knowledge or useful amelioration of unfavorable weather. If this is so, what is needed for the interim period, however short, is a moratorium upon such irresponsible activity.

IN-FLIGHT TECHNIQUES. One way in which this may be accomplished has already been hinted at above. The Civil Aeronautics Board should be requested to investigate and determine whether the modification practices which involve dropping nucleating materials from aircraft in flight "might create any hazard to persons or property," within the meaning of its Civil Air Regulations. It should have access, for this purpose, to classified as well as unclassified information possessed by other agencies and departments of government, and should weigh the possible values of unplanned experimentation against its dangers. If it finds that a hazard may be so created, it can notify airmen and otherwise announce that the dropping of dry ice, silver iodide, or other nucleating material from civil aircraft in flight is a violation of safety requirements and will be penalized in the ways prescribed by law.¹⁰⁹ If necessary, this step could be buttressed by amending the regulation concerning carriage of articles so as to define as "not acceptable" granulated dry ice, silver iodide, and nucleator-dispensing equipment.¹¹⁰

GROUND GENERATION TECHNIQUES. To effect the moratorium upon this type of weather modification activity (of which there appear to have been few instances so far) would require slightly different authority, but this seems also to be available. One of the hazards which irresponsible operation of ground generators may well create is danger to interstate and foreign air commerce. Under existing authority to safeguard this commerce, the Civil Aeronautics Administration has required publication of notice of the erection of ground structures

109. Considerations already mentioned might make enforcement difficult. As a solution to this broader problem, delegation to state courts and aviation agencies of concurrent jurisdiction to enforce the regulations has been recommended in the Report of the Temporary Congressional Aviation Policy Board (1948).

110. 14 CODE FED. REGS. §§ 43.411, 49.2 (Supp. 1945).

which may constitute navigational hazards;¹¹¹ the Board has also regulated the operation of moored balloons.¹¹² Since the effects of ground generator operations, if at all substantial, would extend far into the navigable airspace and inevitably threaten civil airways and control zones, the Board could and should by regulation prohibit these operations.¹¹³

The Regulations would be generally inapplicable to the military aircraft now in use in Government-sponsored experiments, if the military so specified; and where necessary, waivers could be granted for Government-sponsored operations.¹¹⁴ These steps, taken immediately, would furnish a breathing spell during which serious experimentation could continue and more important questions be resolved.

Government-sponsored activity

The experimentation conducted during the suggested moratorium would be by the Federal Government, its contractors, and perhaps state and local governments acting in cooperation with it. The responsibility to press this work forward is a concomitant of the proposed inhibition of activity by others, although that step can be justified upon the basis of hazard alone.

GOVERNMENT AUTHORITY. Some laws considered applicable to weather modification are extant, and legislative proposals directed more specifically thereto have begun to appear. The experiments already conducted by the Weather Bureau have been undertaken under the 1946 amendment to the Civil Aeronautics Act¹¹⁵ which directs the Chief of the Weather Bureau to make studies of atmospheric phenomena for forecasting purposes and to promote and develop meteorological science.

The Civil Aeronautics Act amendment was passed before the present discoveries were made, and a question has lately been raised as to whether it properly authorizes weather control experimentation.¹¹⁶ To

111. 14 CODE FED. REGS. § 525.1 (Supp. 1943).

112. Civil Air Regulations, Part 48, 12 FED. REG. 5910 (1947).

113. The network of civil airways, control zones and landing areas now number hundreds, covering the country in a pattern which experimentation could scarcely avoid; see Regulations of the Administrator, Part 600-01, 12 FED. REG. 4200, 6125, 6764, 8042 (1947).

114. Civil Air Regulations, Part 60, 12 FED. REGS. 5547 (1947).

115. 60 STAT. 944, 49 U.S.C. 603 (1946). The text is: "... the Chief of the Weather Bureau . . . shall . . . (1) make such observations, measurements, investigations and studies of atmospheric phenomena, and establish such meteorological offices and stations, as are necessary or best suited for ascertaining, in advance, information concerning probable weather conditions . . . (7) promote and develop meteorological science and foster and support research projects in meteorology through the utilization of private and governmental research facilities. . . ."

116. See H. Rept. No. 1433, p. 32 (1948).

concede that it was indeed focussed upon research for traditional forecasting purposes only reinforces the conclusion that if national progress in this field is to be continued, and coordination of the developing state and local programs is to be maintained, authority must be enacted which will set this matter at rest.¹¹⁷ A bill introduced by Representative Simpson¹¹⁸ in the 80th Congress, H.R. 4582,¹¹⁹ would reinforce the Bureau's presently existing authority by directing

"that the Chief of the Weather Bureau, after consulting with the Department of Agriculture and other interested Federal and State Departments and agencies, shall conduct such experiments and shall take such further action as may be necessary to perfect at the earliest possible date methods of causing rain to fall and of otherwise controlling the rainfall for any given area."

The defect of such a proposal is readily apparent. Since the physical problem extends beyond control of rainfall, a statute like H.R. 4582 must be broadened to include modification or control of all weather elements.¹²⁰

Other attempts at legislative resolution of the problem have been made at the lower levels of government. State Senator Pruett of Oklahoma has drafted for introduction in that state's legislature a measure authorizing the State Board of Agriculture to induce rain artificially by the in-flight use of dry ice, either in cooperation with the Federal Government or with private contractors.¹²¹ The State Water Survey Division of Illinois, apparently under existing statutory authority, has already engaged in some observational research pertaining to weather control and proposes to continue and expand such activity in cooperation with the Federal Government.¹²² At the local level, the County Counsel of Los Angeles County has recently rendered an opinion that artificial production of rainfall is an authorized public function.¹²³

117. The Department of Commerce urged passage of "H.R. 4582 or substantially similar legislation in order to clarify the authority of the Weather Bureau in this field." Report of the Department of Commerce on H.R. 4582, *Simpson Bill Hearings* 2. Passage was also urged by the Departments of Agriculture and Interior.

118. The writer is indebted to Representative Simpson for copies of much of the legislative material here used.

119. A corresponding bill, S. 2295, was later introduced by Senator Capper. All the proposed federal legislation quoted herein was pending in committee at the adjournment of the 80th Congress, and reintroduction will of course be necessary to revive it. See n. 19 *supra*.

120. See Report of the Dept. of Interior on H.R. 4582, *Simpson Bill Hearings* 3, 4.

121. Copy of his draft was kindly furnished by Senator Pruett. In it, determination of the time and place of operations is vested in the Board, to be exercised upon the basis of "equitable distribution," and the "greatest good of the greatest number of people."

122. *Simpson Bill Hearings* 32. See also an A.P. dispatch in the Austin [Texas] Statesman, July 19, 1948, p. 10, col. 3, referring to this project.

123. Noted in 13 *MUNIC. L. J.* 52 (1948).

GOVERNMENT LIABILITY. The precise wording of the statutory authority for experimentation will bear closely on the question of the Government's ultimate responsibility, if any, for losses. The Federal Tort Claims Act has already been mentioned and its effect must be reconsidered here. One of its dozen exceptions to the general waiver of sovereign immunity withholds jurisdiction to consider or allow:

"Any claim based upon an act or omission of an employee of the Government, exercising due care, in the execution of a statute or regulation, whether or not such statute or regulation be valid, or based upon the exercise or performance or the failure to exercise or perform a discretionary function or duty on the part of a Federal agency or an employee of the Government, whether or not the discretion involved be abused." ¹²⁴

Under the literal wording of the first part of the quoted section, the incorporation into H.R. 4582 of a clear and inclusive authority to conduct research into modification and control of meteorological phenomena (perhaps even "including but not limited to" the specific applications described in preceding portions of this article) would bring the activity, so far as Government is concerned, within the exception. Thus, no liability would fall upon it without negligence. And since discretion must exist in the Weather Bureau to choose the nature, location and time of experiments, having regard to the preexisting and probable atmospheric conditions and the possibilities of damage or hardship, the activity might well fall also within the discretionary portion of the exception.

Such an approach is not necessarily reprehensible or even more than is comprehended by already-existing proposals.¹²⁵ The fact must be faced that these experiments cannot be carried on in our heavily settled country of intertwined ownerships and conflicting interests and at the same time avoid every risk, however small, and however much overbalanced by the benefits which the work is designed to produce. Here is a situation in which "causative factors are . . . difficult to evaluate," and "repercussions" may be "so extensive, their economic impact so considerable, that governmental assumption of liability might entail tremendous expense and large administrative difficulties." The risks are not now calculable and operations do not "predictably involve individually-focussed losses." It has been urged that in such cases:

124. 60 STAT. 842, 28 U.S.C. § 921 (1946).

125. For example, Senator Pruett's proposed Oklahoma statute declares that artificial rain can only partly be considered man-made, and provides regarding legal liability: ". . . any rain that may be superinduced by the use of dry ice . . . is hereby declared to be the Act of God, and no person can predicate any claim for damages on a rain so produced, and the Board of Agriculture and those acting under and by their authority shall be free from all injunction remedies in the execution of the provisions of this Act."

"... as in the case of policy choices which affect the national economy, there are strong arguments against the Government's becoming the guarantor of the financial wellbeing of every citizen who is touched by a decision. Living together in civilized communities is a protection for man; but it also exposes him to occasional perils."¹²⁶

If fuller statutory authority for weather control experiments would bring their conduct within the exceptions to governmental liability, any Congressional attempt to remove the exception and thereby assume the burden of liability should be the product of insight and forthrightness. It would be unfortunate indeed if the problem were evaded by adopting the unsatisfactory substitute of leaving officials with too-scanty authority for what they are intended to do—thus, perhaps, even subjecting them to personal liability.

AUTHORITY TO INDEMNIFY GOVERNMENT CONTRACTORS. The prospect of liability in damages to hordes of claimants may well prove an effective deterrent to continued research by private contractors unless some provision for indemnification is made. Losses resulting from operations carried on by Government contractors should be either shared by Government and contractor (to the extent that the contractor may have insurance) or borne by the nation for whose benefit the work is undertaken. It has already been officially stated that private contractors for weather modification and other scientific researches cannot otherwise be obtained.¹²⁷ To resolve this problem, Representative Andrews introduced into the 80th Congress H.R. 4035, which provides that:

"With the approval of the Secretary concerned, any contract for [scientific] research or development, or both, may provide that the Government will indemnify the contractor against either or both of the following, to the extent that they arise out of the performance of said contract, and are not compensated by insurance or otherwise: (1) Liability on account of claims (including reasonable expenses of litigation or settlement of such claims), by third persons, including employees of the contractor, for death, bodily injury, or loss of or damage to property; *Provided*, that any contract so providing shall also contain appropriate provisions for notice to the Government of suits or actions filed, or claims made, against the contractor, with respect to any alleged liability for such death, bodily injury, or loss of or damage to property, and for control of or assistance in the defense of any such suit, action, or claim, by the Government, at its election; . . . *Provided further*, That no payment shall be made by the Government under authority of this

126. Gellhorn and Schenck, *Tort Actions Against the Federal Government*, 47 COL. L. REV. 722, 740 (1947): cf. Comment, *The Federal Tort Claims Act*, 56 YALE L.J. 534 (1947). Of course, remedy by private bill would still be available.

127. *Hearings before the House Armed Services Committee on Sundry Legislation Pertaining to the Naval and Military Establishments*, 80th Cong., 1st Sess., 3276 (1947).

subsection (b) unless the amount thereof shall first have been certified to be just and reasonable by the Secretary concerned or by an official of the Department designated for such purpose by the Secretary. . . ."

There are objections in some quarters to the precise form of H.R. 4035, but from what has been said, it is clear that this or substantially similar legislation should be enacted.¹²³

WAIVER OF IMMUNITY. The dichotomy in policy presented between H.R. 4035 and the previously-discussed H.R. 4582, as they interact in the present situation, is clearly apparent. Together, they propose that the Government is to be authorized to conduct weather control experiments, and be immune from paying losses unless negligent. But if the same experiments are non-negligently conducted through contractors, and liability is nevertheless imposed on them, the Government is to pay the losses, and thus indirectly adopt a policy of insuring reimbursement to the persons harmed—although its real purpose is only the protection of its contractor. This means that recovery for losses caused by the same kind of activity for the same purpose may depend on no more than the ability of the claimant to implicate a contractor in the activity. Such a distinction is unjust. The decision ought to be made squarely: either the immunity should be extended to contractors or the immunity should be waived in the case of Government as well as contractor.

The most desirable course would seem to be enactment of the legislation embodied in H.R. 4035 without change in substance; at the same time, a waiver of immunity should be inserted into H.R. 4582 or whatever legislation embodies the authority for weather control experimentation. If and when weather control, as distinct from mere hopeful and exploratory interference, is established sufficiently (albeit imperfectly) to become a normal function of government, it will be time enough to apply the theory that the advantages of civilization are the compensation for its much smaller harms and to recognize that the burden of administering examination of millions of separate claims cannot be undertaken. What we have at present is an experiment with a possible new service of government, untried and potentially dangerous. If, as many think, weather modification techniques cannot really change weather, nothing will have been lost by the declaration that Government stood ready to distribute losses ratably. If, however, even though most carefully conducted, they should cause a disaster, the entire loss should not be borne by those whose only fault was to be unfortunate enough to live and have property in the area affected by the experiment—and who have each an interest in weather benefits

123. One such objection is said to be the hardship on contractor of awaiting reimbursement. *Simpson Bill Hearings* 12.

of only one in 140 million.¹²⁹ In the past, especially in the administrative handling of claims, there has been adoption of a view at least as lenient as such a waiver would be.¹³⁰ Proper warning of experiments, publicized as part of the Weather Bureau's usual forecasts (which are more widely disseminated than any order of publication known to the law), would place on those who might be affected the responsibility of using commensurate care to avoid and mitigate possible loss; and only residual losses not otherwise reimbursable would be considered. Of course, the claimant's problems of proof would still be large, and at the least, the records of operations would have to be made available to him.

During the suggested moratorium period, the Government would be party to or have election to defend all claims and could itself ensure full presentation of the considerations which would enable just resolution of those doubtful cases which cannot ever be entirely avoided. If courts then allow liabilities which Congress considers unwisely assumed, the waiver of immunity could be revised. Additional circumstances may be found to alter the case; but the course which seems fairest for the present is that of extending the range of Federal Government tort liability by waiving immunity which exists merely because the activity is in execution of a statute.

The future

It must be reiterated that the inquiries and measures just suggested are purely stop-gap in nature; they must be left behind as speedily as scientific advance permits and requires. If research and experimentation succeed, implementation of the view that weather control is within the public sphere will present a labor of which the observations here made are no more than an earnest. To this national and international task, the treaty and commerce powers are technically adequate, but detailed adaptation will require investigations and improvisations more complex than seem presently recognized.¹³¹

129. See Bohlen, *Aviation Under the Common Law*, 48 HARV. L. REV. 216, 219 (1934), to the effect that subsidization of experimentation by relieving it from liability is incorrect; it is fairer to place the cost upon the public treasury.

130. See AR 25-25, par. 9 (1946), covering small claims arising out of noncombat activities having "little parallel in civilian pursuits" and permitting allowance without a showing of negligence where because of the peculiar nature of the activity or of the resulting damage, "the burden of the loss should be borne rather by the Government than by the particular individual on whom the loss initially fell." An activity historically so considered was the operation of aircraft; cf. AR 25-70 (1947). See also, Comment, *Liability of the United States and Canadian Governments for Tortious Conduct of Their Military Personnel*, 53 YALE L.J. 188 (1943).

131. That international adjustment and ultimately regulation will be the only feasible arrangement has already been suggested. Zworykin, quot. in Kampffert, *Making Weather to Order*, N. Y. Times Mag., July 20, 1947, p. 9. An international meteorological organization has long been found indispensable in weather observation and reporting. Tannehill, *History and Status of IMO*, 28 BULL. AMER. METEOR. SOC. 207 (1947).